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Hunt,
W.A.

PROGRAM DEVELOPMENT FOR MEASUREMENT OF ERODIBILITY OF SPOIL BANKS AND UNTREATED TOPSOIL DUE TO WIND ACTION

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PROGRAM DEVELOPMENT FOR MEASUREMENT OF ERODIBILITY OF SPOIL BANKS AND UNTREATED TOPSOIL DUE TO WIND ACTION

Problem Analysis submitted to

Dr. Edward R. Burroughs, Project Leader
Intermountain Forest and Range Experiment Station
USDA Forest Service
Bozeman, Montana

submitted by

Dr. William A. Hunt, Principal Investigator
Dana V. Cowger, Graduate Research Assistant
Department of Civil Engineering and Engineering Mechanics
Montana State University
Bozeman, Montana

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ABSTRACT

An analysis of the need for a program for measuring the emission of particulates from spoil banks and stockpiles of exposed, untreated topsoil indicates (1) current methods are inadequate, (2) the quantity of particulates emitted from this source is not a significant factor regionally, (3) the emission rate may be very high in the close proximity of the mine site, (4) current methods do not allow for separating amount of emissions from spoil banks and topsoil stockpiles from those generated by haul roads, and (5) existing computer models may serve as a starting point for developing simulation models for predicting emission from spoil banks and topsoil stockpiles.

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PROGRAM DEVELOPMENT FOR MEASUREMENT OF ERODIBILITY OF SPOIL BANKS AND UNTREATED TOPSOIL DUE TO WIND ACTION

INTRODUCTION

Surface mining of coal in the western United States requires the removal and temporary storage of considerable amounts of topsoil and overburden material in order to expose the underlying coal. After the coal layer is removed, the resulting pit is filled with excavated overburden material from an adjacent pit. As this surface mining operation proceeds, the spoils are left in piles or windrows until the reclamation efforts smooths these piles to a finished grade. Topsoil from the temporary stockpiles is deposited over the graded spoils and the site is ready for revegetation. This process creates spoil piles, topsoil stockpiles, and large areas of bare soil materials which are susceptible to wind erosion. Quantities of particulate material may be injected into the atmosphere as a result of the wind action. This may or may not be a significant potential source of air pollution and produce local and regional impacts on human health and on surface water systems through deposition of the particulates. Up to this point, no assessment of the problem has been made.

Purpose

The purpose of this study is three-fold: (1) to determine the significant factors affecting the wind erosion of spoil banks and untreated topsoil, (2) to make an assessment of the potential magnitude of environmental effects, and (3) if the magnitude is significant, to develop a strategy for determining the amount and extent of the area distribution of

particulate matter generated by wind erosion of spoil banks and untreated topsoil.

The scope of the study is a state-of-the-art assessment of the problem limited to gathering and reviewing existing information and investigating the feasibility of studying the problem in greater detail.

Problem Analysis

The analysis of the problem was conducted by (1) visiting various state agencies and mining operations, (2) reviewing existing environmental impact statements (EIS), and (3) reviewing existing literature related to the entrainment, transport, and dispersion of soil particulates by wind action. These three sources are outlined more fully in the following paragraphs.

Information resulting from direct contact with individuals came from two categories of sources: (1) state agencies and (2) mining operations. The state agencies visited were the Department of State Lands and the Air Quality Bureau in Helena, Montana. In terms of mining operations, a field trip was taken to the open pit coal mining operations at Colstrip, Montana. The mine owner, Western Energy in Butte, Montana and the operator, Long Construction in Billings, Montana, were also visited.

The second set of information was obtained by reviewing a limited number of environmental impact statements (EIS). The present consideration and importance given to the wind erosion of spoil banks and exposed topsoil when planning a new open pit mining operation was determined from these studies.

The third source was the review of existing literature related to the problem. The greatest source of literature was made available by the National Technical Information Service. Various other publications were acquired by contacting state agencies in the intermountain region of states. The following sections present the findings of some of the various selected sources.

REVIEW OF CURRENT INFORMATION

The information obtained is presented in the following three subsections: (1) personal contacts, (2) environmental impact statements (EIS), and (3) existing literature.

Personal Contacts

As previously mentioned, two state agencies were contacted: the Department of State Lands and Air Quality Bureau, both located in Helena, Montana. By talking with both agencies, it was possible to become familiar with the agencies' interest in open pit mining operations.

In order to gain an understanding of the actual operations at an open pit coal mining operation, three trips were taken: 1) a dicussion with Western Energy in Butte, Montana who owns the coal mining operations at Colstrip, Montana; 2) a meeting with Long Construction in Billings, Montana who operates the mine at Colstrip; and 3) a field trip to the actual mining operations at Colstrip.

Environmental Impact Statements

By reviewing the environmental impact statments associated with seven existing open pit operations, it was possible to determine the present consideration importance given to the wind erosion of spoil banks and unprotected topsoil when planning new open pit mining operations. Rather than list the studies reviewed in this section, they have been listed with the literature cited. EIS reviewed applied to either present coal mining facilities or more often to proposed mining facilities. The reports pertained to coal mines in Colorado, Montana, North Dakota, and Wyoming.

It was found that in all but one EIS the wind erosion of spoil banks and untreated topsoils was either not mentioned at all or was mentioned in a very general way with no substantiating evidence indicating the degree to which it may be a problem. The one exception was found in the EIS for the Crow Ceded Area Coal Lease; Tracts II and III; Westmoreland Resources prepared by the Bureau of Indian Affairs in Billings, Montana. The EIS reported that "it was empirically determined that, on the average, 58 percent of the particulate loading was due to vehicle dust plumes and 42 percent was due to wind erosion." It is stressed here that the above figures were in no way substantiated and the validity of the figures should be questioned. Due to the unsupported nature of these values, they will not be seriously considered in assessing environmental effects due to the wind erosion of spoil banks and unprotected topsoil.

All anticipated particulate sources, other than wind erosion of spoil banks and unprotected topsoil, have been included in assessing the possible impacts on air quality in the studies reviewed. The effect of wind erosion of spoil banks and exposed topsoil has not been addressed. This might suggest that when preparing an EIS in the past, wind erosion was not considered a problem or was not anticipated as a possible problem. Another alternative is that the particulate emissions due to wind erosion of spoil banks may be insignificant as compared with the emissions from other segments of the operation.

Existing Literature

The primary source of existing literature relating to the problem was acquired from the National Technical Information Service. Various

other publications were obtained by directly contacting state agencies in the Intermountain region of states. This portion of the report presents selected material related to the problem in five subsections. The sections are: (a) factors affecting wind erosion, (b) wind erosion equation, (c) air pollution models, (d) inventory and quantitative data studies, and (e) instrumentation for collecting particulate samples.

Factors affecting wind erosion

The review of existing literature revealed that various publications agree in regard to the factors affecting wind erosion. The general factors are mentioned briefly in this section.

The most obvious factor affecting wind erosion is the wind intensity which is not linearly related to the amount of material eroded [7,26]. The second factor is soil moisture which, as may be expected, tends to decrease wind erosion with an increase in soil moisture [5,26]. Various other factors affecting wind erosion included the following: soil cloddiness, particle size, surface roughness, vegetative cover, surface crust, length and area exposed [5,7,19,20,26]. In the case of wind erosion of temporary spoil banks and freshly graded topsoils, vegetative cover obviously would not apply.

Wind erosion equation

The wind erosion equation has in the past been applicable, on a small scale, to a level field site [6,19].

The wind erosion equation as presented by E. L. Skidmore [19] has the following form:

$$E = f(I', C', K', L', V)$$

I' is the soil erodibility index which considers the particle size and cloddiness of the soil. C' is the climatic factor which is an index of the average rate of soil movement by wind as influenced by moisture content in surface-soil particles and average windspeed. K' is the ridge roughness factor and depends on the height of surface ridges on the field. L' is a factor associated with the width of the field. V is a factor dependent primarily on the vegetative cover of the field.

The wind erosion equation as presented by Skidmore [19] is only a measure of the soil loss and does not measure the amount of particulate that is suspended in the atmosphere. Also, as mentioned before, the equation is only applicable to level terrain on a small scale. This does not, therefore, apply directly to wind erosion of spoil banks and topsoil stockpiles.

In a publication by Chepil, Siddoway, and Armbrust [6], the wind erosion equation was extended to apply to the windward slope of knolly terrain. This however, was only applicable to slopes less than 10 percent which is considerably less than that expected on spoil banks. It is pointed out again that the method does not indicate the quantity of the eroded soil that becomes suspended.

However, the wind erosion equation provides a framework for further study. The specific relationships needed are not available from the literature. The wind erosion equation may be adapted to fit the case of graded topsoil before vegetation emerges. These areas have slopes $\leq$ 20%.

Air Pollution Models

If a study of the wind erosion of spoil banks and topsoil stockpiles was undertaken, it would be necessary to develop systems to satisfactorily model the process. A review of substantial existing literature has revealed that none of the existing models is directly applicable.

In terms of models considering the downwind effect of a particular air pollutant, the Gaussian plume model has been given the most consideration [17]. The model is only applicable to point sources. Since it does not apply to area sources as is the case in the wind erosion of spoil banks, it was given no further attention.

A line-source model by Sutton shown in the Workbook for Atmospheric Dispersion Estimates [23] has been used by PEDCo in calculating the emission rates from unpaved roads. PEDCo also used the Pasquill-Gifford equation [23] to estimate the source strength corresponding to concentration measurements obtained from agricultural sites.

A model for predicting the redistribution of particulate contaminants from soil surfaces was done by John R. Travis [22]. This model deals with contaminant particles eroded from a level area source and then carried downwind. The area source described in the model apparently must be of a rather limited size. This is based on the fact that the downwind particle distribution in the model is described by a Gaussian plume which is only valid for a point source. In its current formulation, the model is unacceptable for application to the wind erosion of spoil banks and topsoil stockpiles but may be a starting point for the development of further models.

Observations of dust flux in the surface boundary layer for steady and nonsteady cases was done by Shinn [24]. This method was also done on level terrain and is not applicable to spoil banks or topsoil stockpiles.

At present there do not seem to be any models which adequately describe the wind erosion of spoil banks. Present models deal primarily with level area sources or point sources which are not applicable to the problem. They may, however, be a starting point for further study in developing a model applicable to terrain typical of spoil banks and topsoil stockpiles when coupled with the methods given by Fesberg, Marlatt, and Krupnak [9] for estimating airflow patterns over complex terrain.

Inventory and Quantitative Data Studies

Existing inventories and quantitative data studies have presented observed values for the amounts of particulate material injected into the atmosphere from a variety of sources. This section defines some of the basic quantities used in such studies and summarizes a few representative studies.

Total suspended particulate and environmental impacts. Total suspended particulate (TSP) is the total weight of suspended particulate in a given volume, usually micrograms per cubic meter ($\mu g/m^3$). This has been and still is the standard used to represent the concentration of suspended particulate. In terms of this definition, the federal air quality standards [21] for total suspended particulates are as follows:

	Primary Sources	Secondary Sources
Annual Arithmetic Mean	75 $\mu g/m^3$	60 $\mu g/m^3$
Max. 24 hr. concentration	260 $\mu g/m^3$	150 $\mu g/m^3$

It should be noted that the definition and values given for TSP in no way accounts for particle size distribution of TSP. Lee Wilson and Associates in New Mexico [13] found that particle size distribution is very influential in assessing the environmental impact. In the remainder of this report, when particle size is referred to, it will imply the equivalent aerodynamic diameter (e.a.d.). The e.a.d. is the diameter of a particle with a density of 1 g/cm^3 which has the same terminal settling velocity as the given particle under consideration.

In terms of health impacts, Lee Wilson and Associates [13] reported that fine particles with diameters between .1 μm and 2 μm have the greatest adverse effects. Particles in this range are inhaled deep into the lungs and deposited. Commonly associated with the fine particle inhalation are respiratory diseases and in some cases cardio-vascular problems and cancer. Impacts are most severe for people with a low tolerance to pollution and are additive to adverse health effects caused by smoking or occupational stresses. Particles of smaller sizes are usually associated with greater toxicity because of deeper lung penetration. Particles with larger diameters, on the other hand, do not penetrate into the lungs because of body filtering mechanisms.

Reduction in visibility may or may not be considered an environmental impact. Lee Wilson and Associates [13] reported that besides producing a health impact, fine particles tend to reduce visibility. Particles less than 1 μm in diameter are effective in scattering light and as a result reduce visibility. It may be noted that since visibility and health hazards are both associated with fine particles, visibility may indicate the overall air quality with respect to particulate material.

In some cases the possibility of adverse effects to vegetation have been considered. Lee Wilson and Associates report that some types of dust seem to have an effect on vegetation but this cannot be readily substantiated. In many cases the adverse effects on vegetation may be related to toxic particulates such as those associated with stack emissions. These types of emissions are not of concern in this study, and therefore impacts on vegetation are not considered further.

In terms of the health effects resulting from coarse particles (>2 μm) the human body's filter mechanisms have the ability to remove the particles thus preventing deep penetration into the lungs. In terms of damage to machinery and other equipment, Lee Wilson and Associates [13] mention that there has been some indication that particulates may cause damage from corrosion. This is usually associated with high moisture and SO_2 which is not of concern in the wind erosion of spoil banks. Other industry representatives have expressed concern that dust increases engine wear through abrasive action. The main problem associated with coarse particulates without SO_2 content is the nuisance problem of soiling windows, excessive amounts of dust in homes, and accumulation in clothing and on the exposed skin areas. The main environmental impact seems to be, without exception, caused by the fine particles in the .1 μm to 2 μm range.

Total suspended particulates (TSP) are not often useful as a measurement of the air quality. Lee Wilson and Associates found that the TSP is not significantly affected by changes in the quantities of fine particles in the .1 μm to 2 μm range. On the other hand, changes in the quantities of coarse particles with diameters greater than 2 μm will significantly change the values for TSP. To stress this point and to emphasize

that environmental impact is associated with fine particles, the following illustration is given. Suppose an air quality program is undertaken to improve the air quality in regard to particulate material. The program selected significantly decreases the amount of coarse particles thus reduces considerably the measure of TSP monitored. For this reason the program is considered a success. In actuality, the environment has not been improved because the fine particles still remain. On the other hand, suppose the program significantly reduces the quantity of fine particles instead of coarse particles. This will not reduce significantly the quantity of TSP monitored and the program will be deemed a failure even though the air quality has been significantly improved. Although the purpose of this study is not to assess the present air quality criteria, it should be noted, however, that when assessing environmental impacts due to particulate material, TSP is not a good indicator.

Existing quantitative data. The authors desired to locate quantitative data that gave measured values of particulate for various sources; in particular, measurements taken at mining sites. The search was limited to Montana where no such data was available. The only data located was the annual air quality data summary for Montana compiled by the Air Quality Bureau in Helena, Montana [10]. The summary consists of measurements taken at various locations throughout the state and reflect only regional values. The samples do not discriminate among sources. This is to say that when the TSP is monitored in a locality where a number of potential sources of particulates may be generated, the fraction of the total attributable to any one source is not positively identified. Methods for identifying specific

sources from the data collected are not currently available without using expensive sophisticated equipment and an extensive field monitoring program.

In the annual summary, the sources are lumped together in the samples listed and this suggests that distinguishing the fractions contributed by the various sources may be difficult or even impossible when setting up a monitoring program.

Existing Particulate Emissions Inventories

Data from particulate emissions inventories are presented to show existing estimates of emissions applying to the wind erosion of spoil banks. Briefly, an inventory primarily consists of identifying all significant particulate sources in a designated region and either measuring or estimating the emissions from the source.

In reviewing available sources of literature, it was found that very little such data is available for the wind erosion of spoil banks. Only two studies consider this source and the resulting data from them are given in this section.

The first such inventory, Investigation of Fugitive Dust--Sources, Emissions and Control by PEDCo-Environmental Specialists, Inc. [16], is an inventory conducted for six control regions located in New Mexico, Nevada, Arizona, and California. Included in the sources were the emissions due to wind erosion of tailings piles (or spoil banks) found at various places throughout the control region. The wind erosion equation for determining the emissions is questionable since, in earlier sections, the wind erosion equation was shown to apply to level terrain. The value (10%) used for the quantity of fines that become suspended is also questionable. It should be

stressed that this value is in no way documented in the report by PEDCo [16]. The data for the wind erosion of spoil banks along with the quantities for other sources of the six control regions is presented in Table 1. The annual emission rates and the sources (area, travel, production) are combined totals for the regions. The emission ratio represents the average for the six region area. The purpose of presenting other unrelated values in Table 1 is for comparisons to be made in subsequent section of this report.

Table 1. Summary of data from <u>Investigations of Fugitive Dust--Sources, Emissions and Control</u> prepared by PEDCo-Environmental Specialist, Inc.

Source	Emissions (tons/yr)	Area, Travel or Production	Emission Ratio
Unpaved roads	762,480	967,462 $\frac{\text{Veh-Mi}}{\text{Day}}$	4.32 lb/veh-mi
Agriculture	1,237,480	4,740,500 acres	.26 $\frac{\text{Tons}}{\text{acres-yr}}$
Construction	151,660	9,091 $\frac{\text{acres}}{\text{yr}}$	16.68 $\frac{\text{Tons}}{\text{acres}}$
Tailings Piles	30,320	11,561 acres	2.62 $\frac{\text{Tons}}{\text{acres-yr}}$
Aggregate Storage	10,100	3559×10^3 tons stored	2.82 $\frac{\text{Tons}}{10^3 \text{ tons stored-yr}}$
Cattle feedlots	4,710	958×10^3 cattle	4.92 $\frac{\text{Tons}}{10^3 \text{ cattle}}$

The value for the emissions from agricultural lands was arrived at by use of the wind erosion equation as were the emissions for tailing piles. The value of the wind eroded material from agricultural land may not be as questionable as that for the spoil banks depending on the slope of the

agricultural terrain. The amount of eroded material from the agricultural land that becomes suspended was assumed to be 2.5 percent in the report. PEDCo [16] defends the 2.5 percent estimate by citing various sources which claim that the amount of particulates suspended is somewhere in the range of 1 to 10 percent. This does not seem to specifically explain or necessarily support the concluded value of 2.5 percent. No field data are presented to substantiate the 1-10 percent range.

The values obtained for the other sources in Table 1 will not be discussed since the methods used seem to agree with currently accepted practice which may not produce reasonable values. It is noted that in Table 1, the effect of particle size distribution is not considered at all.

The second inventory was done for a control region in southwestern New Mexico by Lee Wilson and Associates [13] in Sante Fe, New Mexico. This report was much more detailed in regard to the number of particulate sources included in the study. The study area covered 10,354 square miles of desert basins and range lands, with limited areas of fertile river bottom and mountain forest.

The wind erosion equation was used to determine the emissions from tailings and the amount of eroded material that became suspended was assumed to be 5%. As mentioned earlier, the validity of the wind erosion equation on terrain that is typical of spoil banks is very questionable. As for the 5 percent suspension rate, references cited in the PEDCo report are again used to give ranges of suspension between 1 and 10 percent. It was not possible to determine from the report whether this range applied to terrain found in spoil bank areas. The validity of the 5 percent value is subject to confirmation by field tests.

A summary of values for some selected sources from the report by Lee Wilson and Associates [13] are shown in Table 2. The values in Table 2 represent the total quantities for the types of sources listed for the area studied. As before, the purpose of presenting values in addition to those resulting from spoil banks is for comparisons developed in subsequent sections. The emissions due to wind erosion of range land and crop land were determined by the same method as given in the report by PEDCo [16]. The other emissions presented in Table 2 were arrived at by current practice which, may not produce reasonable values.

Table 2 shows the emissions divided into two size distributions. The fine particles consist of particles with diameters of .1 μm to 2 μm. The coarse particles have diameters ranging from 2 μm to 50 μm. The study also considered a third size range with diameters greater than 50 μm. They are not shown in Table 2 because it is believed that they settle out very near the source.

The validity of the particle size distribution shown in Table 2 at this point is questioned. In a publication by Chepil [4], cited in the report by Lee Wilson and Associates [13], Chepil found no significant amount of suspended particles less than 2 μm. From this, a value of the amount of fine particles entrained and remaining suspended from spoil banks was somehow estimated to be 5 percent of the suspended coarse particles. Similarly a value of 1 percent of the coarse suspended particles was used as the value for suspended fine particles in the wind erosion of crop lands and range lands. It should be stressed at this point that the percentage of fine particles just mentioned for both sources has not been

Table 2. Summary of Selected Data from Suspended Particulates in Southwestern New Mexico, by Lee Wilson and Associates, Inc.

Source	Total (Tons/yr.)	Fine Particles (Tons/yr.)	Coarse Particles (Tons/yr.)	Total Tons/acre-yr.	Fine particles Tons/acre-yr.	$\frac{\text{Fines}}{\text{Total}}$ x 100%
Construction	4,269	395	3,874			6.9%
Unpaved Roads	273,979	22,831	251,138			8.33%
Agricultural Tillage	20.570	5,142	15,428	.22 $\frac{\text{Ton}}{\text{acre-yr.}}$	.056 $\frac{\text{Ton}}{\text{acre-yr.}}$	25.00%
Erosion of Tailings	11,200	560	10,640	2.80 $\frac{\text{Ton}}{\text{acre-yr.}}$	.140 $\frac{\text{Ton}}{\text{acre-yr.}}$	5.00%
Erosion of range, crops	456,000	4,560	451,440	.22 $\frac{\text{Ton}}{\text{acre-yr.}}$	.0022 $\frac{\text{Ton}}{\text{acre-yr.}}$	1.00%
Kennecott Tall Stacks	11,337	7,860	3,477			69.3%
Kennecott Low Stacks	6,298	2,197	5,101			34.88
Phelps Dodge, Tyrone	266	260	6			97.7%
Asphaltic Concrete Plants	2,765	681	2,084			24.6%
Secondary Sources (gas conversions)	75,000	67,500	7,500			90.00%

satisfactorily substantiated in the report by observed data. Since Chepil [4] reported no significant amount of particles less than 2 μm, it would appear that the 1 and 5 percent values are too high.

Most of the other sources listed in Table 2 have particle size distributions which appear to have been determined by common practice--although in some cases are not well substantiated. In subsequent sections, when referring to Table 2, it will be assumed that the particle size distribution for sources, other than those for spoil banks and range and crop lands, are representative distributions for the sources.

Instrumentation for Collecting Particulate Samples

The equipment and devices most commonly used for collecting particulate samples are discussed briefly in the following paragraphs.

The high-volume (hi-vol) air sampler, designed to sample particles between .1 μm to 50 μm [13,25], is the device used most frequently. The hi-vol sampler consists of a sheltered vacuum pump which draws the air through a filter on which the particulate material is trapped. This type of sampler does not measure the particle size distribution. Hi-vols are also noisy, subject to some maintenance problems, do not readily collect the coarser size fraction of particulates, and are not automatic (13).

The dustfall unit is the simplest type of monitoring device. This consists of an open-top cylinder container in which particulate material is allowed to collect. Particles mostly 10 μm and larger are caught and, as reported by Lee Wilson and Associates [13], only provide a "general value" (what is meant by a general value is not indicated).

The "cascade impactor" is a third type. The most common type is the Anderson Head impactor which is attached to a hi-vol air sampler [13,25]. The instrument consists of a series of perforated plates and filters in which material of decreasing size is caught on the succession of filters. This enables the particle size distribution to be determined. Lee Wilson and Associates [13] reported that the particle size distribution may be somewhat inaccurate because some particles may disaggregate while passing through the various filters, and also some coarse particles will naturally end up on a filter thought only to be collecting fines.

The validity of the results of the hi-vol sampler and/or the cascade impactor is questionable. The uncertainty of the reliability is demonstrated in the study by Lee Wilson and Associates [13] who found that samples obtained from each type sampler at the same location were in many cases not comparable to one another for no apparent reason. In one instance, the cascade impactor data may be half that obtained in a hi-vol, and twice that of a hi-vol in another case. One extreme given by the report was a value of 537 $\mu g/m^3$ TSP with the Anderson Head cascade impactor and 86 $\mu g/m^3$ for the adjacent hi-vol sampler. Inconsistencies of this magnitude tend to suggest that programs using the two samplers may not produce reliable results and that when examining the results of monitoring programs, one must consider the type of sampling device.

The three types of sampling techniques mentioned do not include all of the particulate sampling methods. The three mentioned however, do seem to be the most predominent in compiling data for air quality and emission inventories.

Since 1973 the Environmental Protection Agency (EPA) has sponsored six research and development projects [2,8,12,14,15,18] on the measurement and control of fine airborne particulates. The devices developed by these projects address the measurement of fine particulates in emissions from stacks where the gas (or air) stream to be sampled is confined to a closed conduit. An extensive study of these reports indicates that these devices could be used in open field or atmospheric sampling stations only with difficult and expensive installation methods.

ANALYSIS OF INFORMATION

Observations and conclusions concerning the magnitude of the problem caused by wind erosion from spoil banks and exposed topsoil based on the infromation from existing reports are presendted in the following paragraphs.

Fine Particles

The reports and literature indicate that, without exception, fine particles are associated with adverse environmental affects. The purpose of this study is not to assess air quality criteria but it should be noted again that TSP is not a good indicator of the quantity of fine particles in suspension. This shows TSP to be somewhat inadequate as a description of air quality.

As was indicated in a previous section, a completely reliable method of measuring the quantity of fine particles is not available with conventional instrumentation devices. Another difficulty in getting an accurate measurement of the concentration of fine particles from a given source (spoil bank and exposed topsoil emissions) is the inability to identify the specific sources when taking measurements. It may be nearly impossible to measure particulate materials from one source without receiving contributions from surrounding sources. This is particularly true for sources having the areal expanse of spoil banks located in a semi-arid regional environment.

Magnitude of the Problem

The lack of reliable field data for particulate emissions from spoil banks render it impossible to compare spoil banks to other sources. The accuracy of the values presented in Tables 1 and 2 for the emissions from

spoil banks should again be mentioned. The emission values were determined by utilizing the wind erosion equation to estimate the total eroded material then estimating the amount of suspended particulates as a percentage of the total material. The validity of using the wind erosion equation for determining the quantity of material eroded from spoil banks with steep slopes is subject to question. The assumptions used in determining the 10 percent emission quantity by PEDCo [16] and the 5 percent emission quantity by Lee Wilson and Associates [13] were also suspect since little or no documentation was cited. It is assumed, for the purpose of comparison, that the values in Tables 1 and 2 are representative due to the lack of more reliable data.

The relative quantity of emissions for various sources can be seen in Table 1. At first glance the comparison of the emissions due to wind erosion of range land and crop land (0.26 tons/acre-yr) with that due to the erosion of tailings (2.62 tons/acre-yr) shows an order of magnitude difference. This comparison, however, may be slightly distorted because the emissions from the wind erosion of range land and crop land is an average and does not separate quantities for severely erodible soils and mildly erodible soils. On the other hand, a comparison of tailings emissions (2.62 tons/acre-yr) with that from construction (16.88 tons/acre-yr) indicate a considerable difference, with tailings emissions being about one-sixth that of construction. Unfortunately, the values for the other given sources cannot be directly compared with that of tailings piles because of the inconsistency in units. The total values for a given source, however, for the inventory regions can be compared. It is noted that on a total regional basis, the emissions from unpaved roads (762,480 tons/yr) as

compared with that from tailings piles (30,320 tons/yr) is considerably higher. This does not say anything about the local effects but it may indicate, to some degree, the regional effects. This, however, can not be substantiated without taking into account the overall inventory area.

As pointed out earlier, the quantity of fine particles is of primary concern when assessing environmental impacts due to particulate material. On this basis it is difficult to come to any meaningful conclusions from the data presented in Table 1 since the data do not consider particle size distribution.

The data present in Table 2 indicates particle size distribution. The validity of the particle size distribution for emissions by wind erosion from tailings piles is not documented. The values given for fine particles from tailings piles (5% of coarse particles) is subject to question as studies by Chepil [4] indicate that the amount of fines is actually less than 5 percent. Even though the values for the fine particle content for tailings piles emissions are questionable, it will be assumed, due to a lack of any other sources, that the values are representative for the purposes of comparison.

Table 2 reveals approximately the same values of TSP resulting from spoil piles (2.80 tons/acre-yr) as those presented in Table 1 (2.62 tons/acre-yr). On a per acre basis, tailings contribute about 60 times the quantity of fines as do range and croplands. At first glance this appears to be significant, but later paragraphs tend to show that spoil bank emissions are, as compared with other sources, not very significant.

A comparison is made of the emissions from agriculture tillage and tailings piles to show the effect of particle size distribution. Note, from

Table 2, that the TSP resulting from agriculture tillage (.22 tons/acre-yr) is approximately 1/10 that resulting from spoil banks, but tillage contributes about one-half to as many fines as tailings piles. This suggests that tailings piles emissions may not be that significant in comparison to agricultural tillage when the total number of acres involved are considered. (Text of report from which Table 2 was extracted indicates 91,830 acres of agricultural tillage and 4000 acres of tailings piles in the study region.)

The following comparison tends to suggest that environmental impacts due to erosion of spoil banks is insignificant in comparison to other given sources. In Table 2, an emission of 11,227 ton/yr is given for the Kennecott tall stacks owned by Kennecott Copper Corporation. This compares with the value of 11,200 tons/year for that of tailings piles. It is noted here that the Kennecott emissions are considered to have a much greater intensity since they occur at a point while the tailings piles emissions occur over 4000 acres as given by Lee Wilson and Associates [13]. When particle size is taken into consideration, the problem is further emplified. The amount of fine particles from tailings piles emissions from Table 2 is found to be 560 tons/yr distributed over 4000 acres (.14 ton/acre-yr) compared to 7,860 tons/yr for the Kennecott stacks concentrated at a <u>point</u>. The possibility of toxic chemicals from the stacks is also apparent. This alone tends to dwarf the effect of the tailings piles emissions. In comparing other stack emissions in Table 2 with tailings emissions, this same trend holds.

As was the case with Table 1, it is not possible in Table 2 to compare spoil bank emissions with those from unpaved roads on a per acre basis. It

is significant to note that for the entire control region (10,345 mi^2) the quantity of emissions from unpaved roads (TSP = 273,969 tons/yr, fines = 22,831 tons/yr) is considerably higher than for spoil banks (TSP = 11,200 tons/yr, fines = 560 tons/yr). This does not consider the impact on a local basis, but it may suggest that on a regional basis that emissions from spoil banks have much less effect than unpaved road emissions.

The limited number of comparisons given in previous paragraphs did not show which sources present serious problems. It did, however, allow a comparison of the effects of various sources. The comparisons suggest that the emissions from spoil banks due to wind erosion are, in some cases, as significant as a few of the other sources, but in most cases seem to be relatively insignificant. This is especially true when comparing stack emissions with tailings emissions in Table 2. It should be stressed here that the previous discussion has been predicated on the assumption that the values given in Tables 1 and 2 are representative quantities. As was mentioned before, in the case of spoil banks, this may not be a valid assumption.

Importance of the EIS

The importance of environmental impact studies in assessing the impact of particulate emissions of spoil banks will be briefly mentioned.

Environmental impact statements have not really addressed the problem of air quality degradation by wind erosion. It may be possible that in planning new facilities, wind erosion of spoil banks and untreated topsoil was not anticipated to be a problem. Another possibility is that wind erosion of spoil banks has not been considered a problem or is relatively

insignificant in comparison to other emission sources. This alternative was suggested earlier and appears to be substantiated by the examples in the previous section.

NEED FOR ADDITIONAL STUDIES

The need for additional studies of wind erosion from spoil banks of strip mining operations should consider three fundamental questions: (1) How significant is the potential for air quality deterioration on a regional basis? (2) How significant is the potential health hazard and nuisance problem on a local basis? and (3) How accurate must the estimates of emission rates from spoil banks and exposed topsoil be?

An insight to the regional aspect is given by the Wilson study [13] which indicates that the quantity of emissions from unpaved roads is far greater than from mine spoil banks. Although emissions from specific operations at the mine sites cannot be distinguished, it is worthy of noting that in Air Quality Control Region 143 in Eastern Montana the TSP at Colstrip had a geometric mean concentration not too different from that noted at Fort Peck and Glendive for the period January 1 - December 31, 1975 [10]; the values given in micrograms per cubic meter are 18.6, 15.4 and 18.9, respectively. The monitoring site at Colstrip is in the proximity of the tipple for loading unit trains with coal. This would indicate that the TSP in the vicinity of the strip mining activity at Colstrip is not appreciably different from the ambient air in other parts of the region not adjacent to such activity. As studies by Wilson [13] and PEDCo [16] indicate, the emissions from unpaved roads are much greater than from tailings piles, and it would seem that the former source is more significant on a regional basis.

The potential health hazard and nuisance problem of wind erosion and transport of particulates from spoil banks may be very significant locally, especially, if residential and commercial buildings (not associated with the mining operations) are within the zone of deposition of the suspended particulates. As the deposition zone is determined by the size of the soil particles, the direction and magnitude of the wind velocity, the aggregation of the soil particles and the soil moisture content, an exact boundary of the zone of deposition cannot be determined. However, an examination of the aerial mosaics of strip mining operations and a visit to a mine site on a hot, dry, breezy day in which the haul roads were not being wetted down, verified the findings of PEDCo and the Wilson studies concerning the relative magnitudes of the emissions from paved roads and from the wind erosion of spoil banks. The haul roads in the pit area and from the excavation site to the tipple generally are located adjacent to the spoil bank areas; a condition which would make monitoring the emissions from these two individual sources extremely difficult. The emissions from the unpaved roads are much more noticeable than the erosion from spoil banks.

The accuracy of the estimates of the emission rates from wind erosion on spoil banks is determined by the purpose for making such estimates. The two extremes for accuracy may be illustrated by the following examples: (1) particulates are transported from spoil banks left untreated by mining operations in an area no longer serviced by haul roads, or any significant traffic, to a new residential area causing a nuisance and potential health problems, and (2) a new mining operation is being planned and a reasonable

estimate of the TSP from the operation is to be obtained for planning purposes. The accuracy of the estimate for the first case will need to be sufficient to be used as evidence in public or court hearings. The accuracy of the estimate for the second case is not as great as this will be used only for planning emission control strategies.

The time and effort committed to any additional studies of the wind erosion of spoil banks (and exposed topsoil) will be dictated by two factors:

1. The importance of the emissions rate caused by wind erosion of spoils relative to that of fugitive dust from haul roads.
2. The importance of the accuracy of emission rate estimates.

The methodology of additional studies should include two phases: (1) development of a reasonable analytical model based on previous wind erosion studies and (2) verification of the model by field tests.

Research Methodology

The initial phase of determining the emission rates of particulate matter suspended and transported from spoil banks through wind erosion is a step-wise development of a computer model to simulate the wind erosion process. A review of the literature of wind erosion predictions for agricultural lands [3], blown desert sand [1], dispersion of pollutants through the wind in the atmosphere, and the associated boundary layer theory of fluid mechanics [11] indicates that a body of information necessary to provide a starting point for developing a model (or models) suitable for simulating emission rates with an accuracy appropriate for planning mining operations is available. Additional study of the available information will determine if it is sufficient to complete the development.

The starting point for such a development is to examine the wind erosion equation for agricultural lands given by Woodruff and Siddoway [26]:

$$E = f(I', C', K', L', V).$$

The adaptability of this equation to the irregular topography of spoil banks needs to be evaluated. A re-evaluation of the soil erodibility, I'; the local climatic factor, C'; surface length, L'; and surface quality V would require considerable study of the effect of the irregularity of the terrain on parameters. This study would require a verification of results through a substantial program of field work. A much more promising approach is to obtain the documented computer programs for modeling the redistribution of particulate contaminants by Travis [22] and for estimating airflow patterns over complex terrain by Fosberg, Marlatt and Krupnak [9]. It may be possible to integrate these programs into a single program to simulate wind erosion from the spoil banks.

The model developed by Travis [22] describes the relocation of wind-eroding soil containment mixtures by first characterizing soil and surface conditions within a square mesh overlayed on the surface. Then, according to certain meteorological conditions, a horizontal flux component transports material into adjacent mass conserving cells, and a vertical flux component generates puffs of suspendable particles. These puffs are diffused downwind under time-dependent wind velocity and atmospheric stability conditions, maintaining a three-dimensional Gaussian distribution of particulate concentration with the cloud volume during the interval. Each puff has a center, volume, and material mass which are determined by the wind velocity, atmospheric stability, travel distance, and deposition

velocity. After material is deposited at new locations, the redistribution process may recycle to provide additional particulate movement from these new sources. The utilization of this program depends on a limited amount of field work to describe the soil and surface conditions for determining the horizontal and vertical soil flux components given by Chepil [3], Bagnold [1], and Gillette [11]. These flux components are dependent on the friction velocity, $\sqrt{\tau_o/\rho}$, in which τ_o is the shear resistance at the surface and ρ is the density of the fluid carrier (the air, in this case).

The application of the Travis program to spoil banks requires a suitable system for modeling the wind patterns over the irregular terrain. The Fosberg-Marlatt-Krupnak (FMK) program based on reasonable simplifications to the complete set of equations governing flow over complex terrain presents the methodology suitable for augmenting the Travis model with the wind velocity patterns over spoil bank topography. Case studies using the FMK program indicate that the model could be used to aid in planning air quality programs. The authors also evaluated the model against six case studies conducted in Oregon and one in California. The strength of this model lies in the minimal amount of input data required: temperature, pressure, elevation and a suitable roughness coefficient of the underlying surface.

The second phase of the development of emission factors for wind erosion of spoil banks is a field validation or calibration of the model (or models) adapted for making the predictions. The amount of field work for the methods proposed, i.e., modification of the wind erosion equation and development of a model from the existing Travis and FMK programs, is significantly different.

The evaluation of the parameters for the wind erosion equation, or a modification thereof, requires an extensive program of field observations of wind data (magnitude, direction, and frequency), soil characteristics, climatic factors, quantifiable terrain features, and measurements of TSP at several sites in the immediate proximity of the spoil banks. The purpose of the studies is to obtain sufficient detailed data logs of the weather, climatic, and time-dependent quantities of particulate matter in the atmosphere to develop suitable modification for the parameters. The type and quantities of data and development of suitable multiple joint distribution correlations indicate this approach to be expensive and time consuming.

The field studies associated with the development of the computer simulation model are required to determine only the physical characteristics of the soil, the terrain, and atmospheric conditions for use in evaluation of parameters used as constants in the program. Field studies are also required for developing the functional relations among the parameters as in modifications of the wind erosion equation.

The historical weather records will be used as input for cases to be simulated. The calibration (or evaluation) of the model is accomplished by using the weather records as input data to the model, establishing a network of sampling stations in the vicinity of the spoil banks, and checking the total deposition at selected points against that predicted by the simulation model over a given period of time.

The simulation model would be developed in a general fashion for utilization for wind erosion suspension, transport and deposition at any mining site.

CONCLUSIONS AND RECOMMENDATIONS

Based on this study of wind erosion of spoil banks and exposed topsoil, generated as part of the strip mining operations, the following conclusions are drawn:

1) estimates of the amount of particulates in the atmosphere from wind erosion of spoil banks are calculated using a figure of 2 to 10 percent of the soil loss determined from the wind erosion equation,

2) the quantity of total suspended particulates in the air as a result of wind erosion of spoil banks is at least an order of magnitude less than the quantity resulting from traffic on unpaved roads,

3) the amount of particulates in the air as a result of wind erosion of mine spoil banks is not a significant factor in regional air quality inventories,

4) it is difficult to monitor the quantities of total suspended particulates attributable to wind erosion of spoil banks in mining operations because of the proximity of other activities generating particulates in the area.

5) the data and studies existing in the literature on wind erosion, modeling air patterns over complex terrain, dispersion and transport of particulates in the atmosphere, and the factors related to entrainment of soil particles in air streams may be sufficient to develop a suitable computer model for simulating the effects of wind erosion of spoil banks, and

6) a field evaluation of the model conducted at three to five mine sites with a network of four to six monitoring stations at each site

operating intermittently through the seasonal changes in weather and other climatic factors is required to make the model operational.

If the current methods of predicting the total suspended particulates generated by wind erosion of spoil banks are insufficient for the purposes of the current studies, it is recommended that:

1) a computer program be developed based on a) the work of Travis reported in the paper "A Model for Predicting the Redistribution of Particulate Contaminants from Soil Surfaces," and b) the work of Fosberg, Marlatt, and Krupnak as reported in the U.S. Forest Service Publication, "Estimating Airflow Patterns Over Complex Terrain."

2) a field program be established to calibrate the simulation model (techniques to evaluate the soil parameters and climatic conditions for a number of sites in the Intermountain area appears to be available through other studies).

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